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The return of the Blue Crab, *Callinectes sapidus* Rathbun, 1896, after 70 years from its first appearance in the Gulf of Trieste, northern Adriatic Sea, Italy (Decapoda: Portunidae)

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Abstract: Since August 2015, an increasing number of Blue Crabs, *Callinectes sapidus* Rathbun, 1896, have been reported in the Marano and Grado Lagoon, Gulf of Trieste, in the northern Adriatic Sea. This species is not a new introduction and in fact the first record of *C. sapidus* in Italy and the entire Adriatic Sea dates back to 1949 in the Grado Lagoon. Interestingly, no other records of *C. sapidus* have been reported since the first record. Here, we note the re-appearance of *C. sapidus* in the Gulf of Trieste.

Key words: invasive species; re-appearance; Marano and Grado Lagoon; Adriatic Sea

The American Blue Crab, *Callinectes sapidus* Rathbun, 1896 (Decapoda: Portunidae) is a euryhaline and eurythermal invasive species in Europe. Its native range is the western North Atlantic Ocean from Nova Scotia to Argentina. However, during the last decade, its range has expanded, either accidentally or deliberately, into both Asia and Europe (Galil 2000). The first record in Western Europe was from the Biscay Gulf, France, in the early 20th century (Bouvier 1901). Since then, this species has been reported from the North Sea (Netherlands in 1932, Belgium in 1981, and Germany in 1965) (Den Hartog and Holthuis 1951; Kühl 1965; Adema 1991; Gollasch 1996) and in the Baltic Sea in 1951 (Denmark) (Wolff 1954; Knudsen 1989; Gollasch 1996). It has been found along the coasts of Britain in 1982 (Clark 1984; Minchin et al. 2013), Portugal (Gaudêncio and Guerra 1979), and Spain (Cabal et al. 2006).

Starting in the late 1960s, *C. sapidus* was observed in Bulgaria (Black Sea) (Bulgurkov 1968; Petrescu et al. 2000), Russia (Azov Sea) (Diripasko et al. 2009; Pashkov et al. 2012), Ukraine (Monin 1984), and Georgia (Shaverdashvili and Ninua 1975). Records are being continuously updated, and the most recent sighting was off Turkey (Yağlıoğlu et al. 2014).

Callinectes sapidus reached the Mediterranean basin in ships' ballast tanks (Holthuis and Gottlieb 1955), but the timing is unknown (Castriota et al. 2012). This species was in fact often mistaken for *Portunus segnis* (Forskål, 1775) and often had been called *Neptunus pelagicus* or *P. pelagicus* (Linnaeus, 1758) until the *P. pelagicus* species complex was revised (Lai et al. 2010).

Callinectes sapidus was reported from the Ebro delta, Spain (Tuncer 2008) and Guadalquivir, southern Iberia (Cabal et al. 2006), suggesting an active expansion of range of this species toward southern latitudes in estuaries (Ribeiro and Veríssimo 2014). In the Mediterranean, *C. sapidus* is known from Malta (Sciberras and Schembri 2007), the Ligurian Sea (Tortonese 1965; Bisconti and Silvi 2005), the Aegian-Levantine Sea basin (Serbetis 1959; Enzenrob et al. 1997; Zaitsev and Öztürk 2001), and the Ionian Sea (Molnar et al. 2008; Thessalou-Legaki et al. 2012).

In the Adriatic Sea, *C. sapidus* was first recorded in 1949, as *Neptunus pelagicus,* from Grado Lagoon (Giordani Soika 1951). The correct identity was established in 1993 following the discovery of two males in the Venice Lagoon in 1991 and 1992 (Mizzan 1993).

Many records were reported from the Adriatic Sea, along both western (Gennaio et al. 2006; Scaravelli and Mordenti 2007; Florio et al. 2008; Castriota et al. 2012; Mancinelli 2013; Cilenti et al. 2015; Manfrin et al. 2015) and eastern coasts (Tuncer 2008; Beqiraj and Kashta 2010; Dulčić et al. 2010; Dulčić et al. 2011). However,

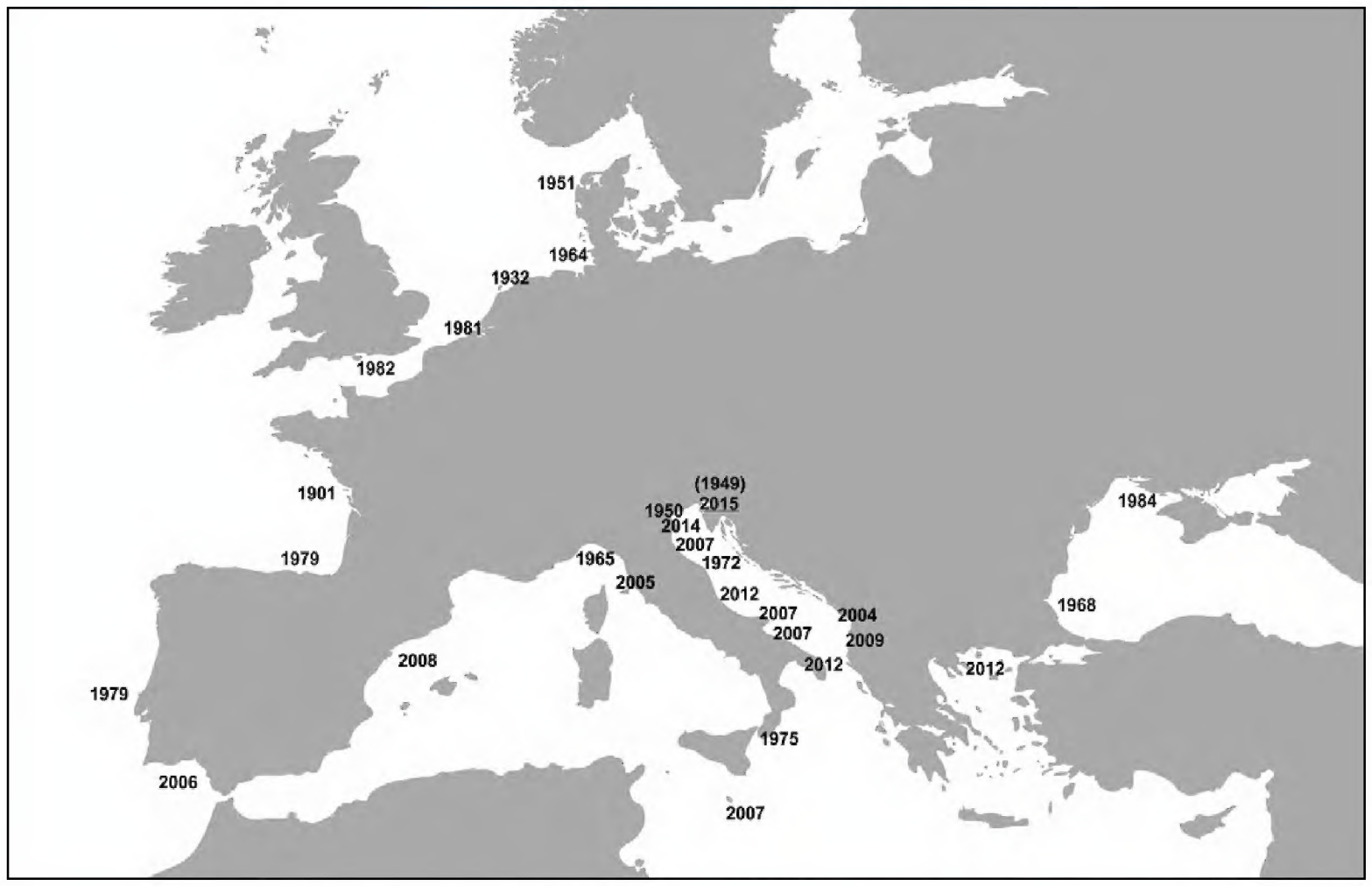


Figure 1. Locations and year of first appearance of *Callinectes sapidus* in Europe and Italy. The literature on which this is based is cited in the text.

no other *C. sapidus* have been collected from the Gulf of Trieste, until now. First records for *C. sapidus* in European waters are summarized in Figure 1.

Here, we document the occurrence of *C. sapidus* in the Gulf of Trieste, 66 years after the previous (and first) record from the same area (Giordani Soika 1951).

The Gulf of Trieste is divisible into two main sectors that are separated by the Timavo River. The first sector extends to the sandy Grado littoral zone at west, whereas the second sector extends from the Timavo River to the Istrian littoral and is characterized by rocky coastline. The Gulf includes the Marano and Grado Lagoon.

The Marano and Grado Lagoon is one of the most ecologically intact wetlands in the entire Mediterranean area. The lagoon complex, between the deltas of the Tagliamento and Isonzo rivers is approximately 32 km long, up to 5 km wide, and has an area of 160 km^2. The surrounding drainage basin (1,880 km^2) delivers important loads of both nutrients and pollutants (Covelli et al. 2012; Saccon et al. 2013). Since 1971, the lagoon is protected by the Ramsar Convention. Following the implementation of the Habitats Directive (92/43/EC), which concerns the protection of biodiversity, it is also identified in the state-sponsored "Natura 2000" survey as a Site of Community Importance (SCIs IT3320037). The area is economically important, supporting tourism and industry. There are recreational fisheries (mainly the *Venerupis philippinarum* [A.Adams & Reeve, 1850], Manila Clam) and with fish farming (Acquavita et al. 2014). According to the Water Framework Directive 2000/60/EC, three main water types were identified in the Marano and Grado Lagoon: mesohaline TME (5–20 PSU), polyhaline TPO (20–30 PSU), and euhaline TEU (30–40 PSU) (Bettoso et al. 2010).

Five specimens of *C. sapidus* were collected between late August 2015 to September 2016 (Table 1) within the Marano and Grado Lagoon (Figure 2).

Collection of the specimens numbers 1, 2, 4, and 5 (Table 1) was done using fyke nets with the help of local anglers, A fyke net consists of a barrier of about 60 m in length and 1.3 m in height, with a mesh size of 1.6 cm, which leads fish and shrimp towards four cone-shaped, unbaited traps also with the same mesh size. This fishing gear, with the barriers set perpendicular to the tidal flow, takes advantage of tidal dynamics to catch fish and shrimp (Malavasi et al. 2004). Specimen

Table 1. Collection sites of each specimen, along with date of collection, size expressed as carapace width and sex. Voucher ID ZI-06635 is within the collection of the Museo Friulano di Storia Naturale of Udine (via Sabbadini, 32, 33100, Udine, Italy), while voucher ID c485 is stored and is part of the collection of the Civico Museo di Storia Naturale of Trieste (via dei Tominz, 4, 34139, Trieste, Italy). Pictures of each specimen are reported in Figure 3.

Site no.	Site	Geographic coordinates	Date collected	Carapace width (mm)	Sex	Voucher	Figure
1	Marano Lagoon	45.70° N, 013.11° E	27 August 2015	160	♂	ZI-06635	Figure 3a
2	Marano Lagoon	45.70° N, 013.20° E	30 September 2015	176	♀	—	Figure 3b
3	Grado Lagoon	45.70° N, 013.35° E	29 October 2015	190	♂	c485	Figure 3c
4	Marano Lagoon	45.70° N, 013.08° E	26 August 2016	177	♂	—	Figure 3d
5	Marano Lagoon	45.70° N, 013.20° E	9 September 2016	158	♂	—	Figure 3e

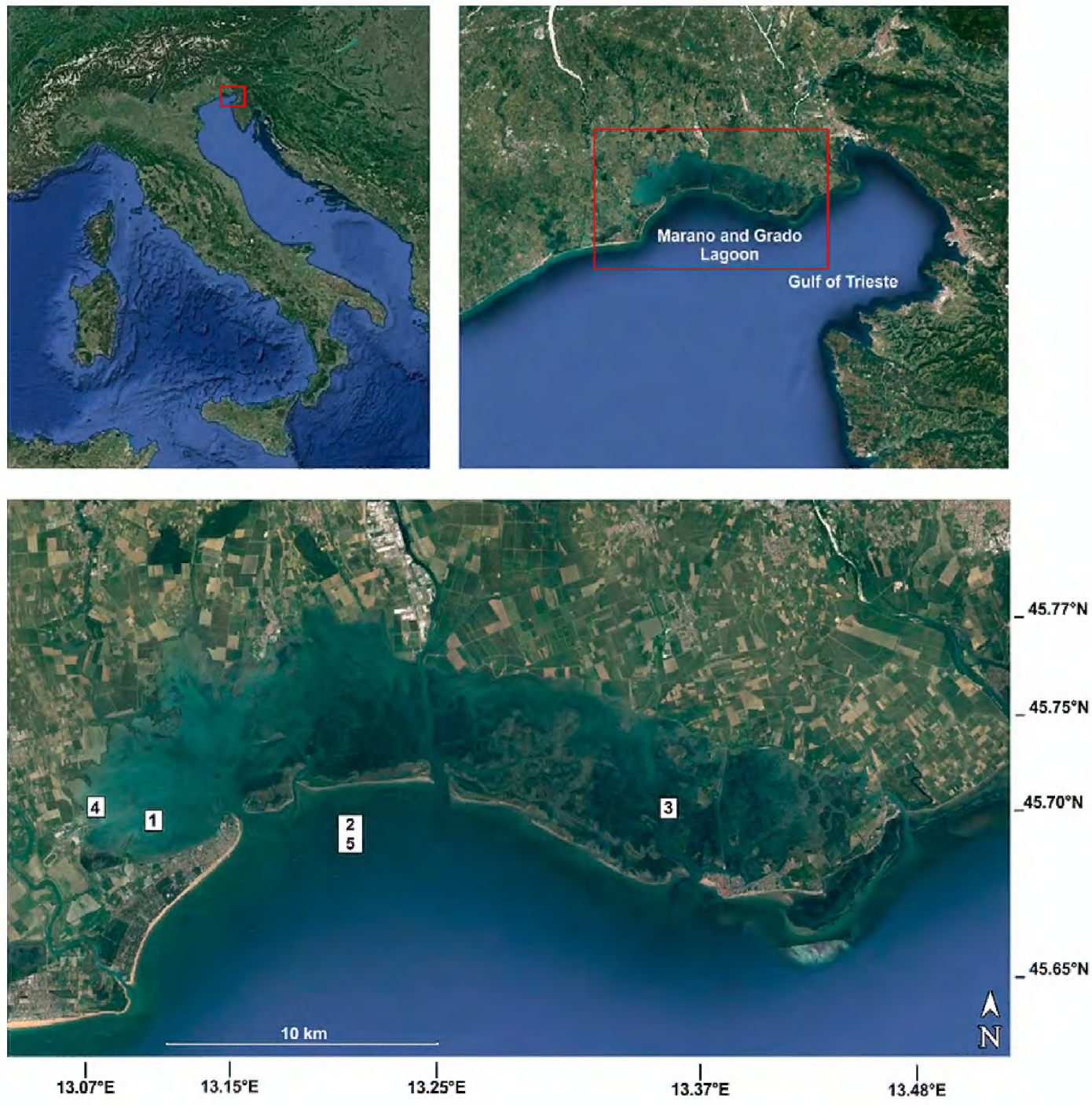


Figure 2 Map of the Gulf of Trieste showing collecting sites (white dots) for each of the five specimens (site numbers correspond to those in Table 1).

number 3 was collected in water about 4 m deep by mean of trammel net.

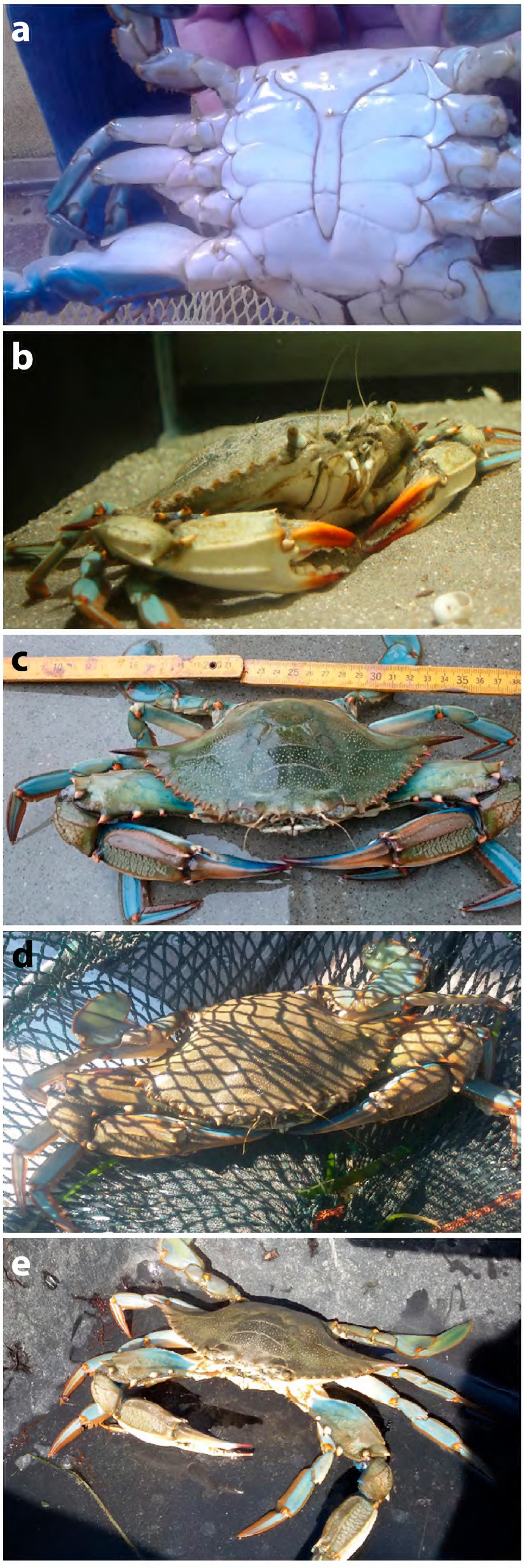
Specimens (Figure 3) were identified according to Williams (1974) and Galil et al. (2002). We identified the species *in loco* and later one of us (JSC) confirmed the identificiation using photographs. The carapace width (CW, maximal distance between the posterior anterolateral spines; Table1) and sex were recorded for each specimen. *Callinectes sapidus* is characterized by an intense blue color of the appendix. The remainder of the exoskeleton is olive-brown. As with other portunid crabs, the fifth leg is paddle-shaped, adapted for swimming. The genus *Callinectes* is distinguished from other portunid crabs by the lack of an internal spine on the carpus (the middle segment of the claw), as well as by the T-shape of the male abdomen (Williams 1974). Males and females of *C. sapidus* can be distinguished sexually dimorphic shape of the abdomen: males possess a structure, called the apron, shaped as a long, narrow, inverted "T" (Figure 3c), whereas in females, the apron is wider, rounded, crescent-shaped (Williams 1974).

Specimen number 1 (Figure 3a) was deposited in the Museo Friulano di Storia Naturale of Udine (ZI-06635), and specimen number 3 (Figure 3c) was deposited in the Civico Museo di Storia Naturale of Trieste (c485).

About 70 years ago one specimen of *C. sapidus* was found near Grado (Giordani Soika 1951). Subsequent to this record, no additional specimes of *C. sapidus* have been found in the Gulf of Trieste until now.

According to the Harding's (2003) classification, crabs can be divided into three size groups (small, CW < 80 mm; medium, CW 80–120 mm; and large, CW > 120 mm) and our specimens are fit the large category. All the specimens were caught in water where salinity is greater than 30. Dulčić et al. (2011) observed that populations of *C. sapidus* are partitioned by sex: males prefer more brackish water (20–25 salinity), whereas adult females tend to concentrate in higher salinity waters (> 30). We cannot confirm those observations by Dulčić et al. because our four male and one female specimens were collected high salinity water (> 30). Salinity is important for the development of this species' eggs and larvae (Costlow 1967), and therefore, adult females are expected to be more numerous in more saline environments, and they migrate further out into the coastal waters for spawning (Steele and Bert 1994; Murphy et al. 2001).

To date, no larvae have been caught in the Gulf of Trieste, based on observations exclusively of anglers who are not generally focused on larvae. We speculate that larvae are carried in ships' ballasts from other



areas. Once released into the Gulf, a small number of larvae might grow to adulthood, but we do not have evidence of this at this time. We know of at least 12 adult individuals of *C. sapidus*, the five we caught and others eaten by anglers, but others may have been found by anglers. We also do not know if juveniles are present. It is possible that changes in environmental conditions may contribute to the spread and growth of *C. sapidus* in the Gulf of Trieste.

From 1949 to 2014, the mean annual temperature of the sea has increased by about 1°C (data not shown and personally provided by Dr. F. Raicich from Institute of Marine Sciences of the National Research Council (CNR) of Trieste). However, this increase seems not to explain our new records of *C. sapidus* because it is already established in the North Sea, where temperatures are much lower than the Adriatic. Other environmental conditions (salinity and organic load) should be considered but long-term data are not available.

Dulčić et al. (2011) and Beqiraj and Kashta (2010) gave evidence of an established population elsewhere in the Adriatic Sea (Neretva River delta, Croatia, and Patok Lagoon, Albania, respectively). Due to invasiveness of this species, the Marano and Grado Lagoon and the offshore areas could provide favorable conditions for the establishment of a population of *C. sapidus* in this area. This species is an omnivore, feeding on fishes, mollusks, crustaceans, and algae. It has a complex life history and utilizes both marine and estuarine habitats (Hines et al. 1987).

The Marano and Grado Lagoon is among the most important areas in Italy for Manila clam production, and in 2010, production was 1,042 tons (Sladonja et al. 2011). The Marano and Grado Lagoon also represents an important habitat for fish and a nursery ground for juveniles. The lagoon hosts the two most important ports, Marano Lagunare and Grado, for fisheries in the Friuli Venezia Giulia region (Bettoso et al. 2013).

Thus, a significant increase of *C. sapidus* might have severe consequences for the autochthonous ecological communities, as well as for the shellfish farms and artisanal fishery, by preying on bivalves and damaging fish nets, pots, and the fish caught inside. On the other hand, *C. sapidus* is considered a delicacy and is harvested not only as hard-shell crabs but also as peeler crabs just prior to molting and soft-shell crabs immediately after molting. The large consumption of *C. sapidus* in North America and Europe, as well as Japan, is supplied by major commercial fisheries (Branco and Fracasso 2004). Therefore, *C. sapidus* should be promoted as a new food source locally and might reduce its potential negative impacts on the indigenous fauna (Dulčić et al. 2011; Župan et al. 2016).

Figure 3. *Callinectes sapidus* from the Marano and Grado Lagoon. Morphometric and other information on each animal are reported in the Table 1.

It is paramount that the presence, establishment, and abundance of *C. sapidus* populations be monitored so that the potential impacts of this alien species on the biodiversity of the region, as well on bivalve production, are known. Globally, the second most serious threat to biodiversity is invasive species (Genovesi 2002); only habitat loss and fragmentation is more serious (Florio et al. 2008). Efforts to constantly update new invasive decapod species in the Marano and Grado Lagoon, such as *Palaemon macrodactylus* Rathbun, 1902 (Cuesta et al. 2014) and *Eriocheir sinensis* H. Milne-Edwards, 1853 (Bettoso and Comisso 2015), are useful information for management and conservation plans. More introductions of invasive species into the Mediterranean are expected in the coming years, especially with the recent expansion of the Suez Canal. Continuous monitoring and updates are needed to assess, whether the presence of *C. sapidus* is random and incidental, as in the case happened in 1949, or if a population, even small, of *C. sapidus* is being established. The propagule pressure (Lockwood et al. 2005) it is not known and the framework of the invasion is under observation, it could putatively be between C1 and C3 category of the unified framework for biological invasions (Blackburn et al. 2011). In addition, the Gulf of Trieste is an important site for mollusk's production, and the impact of blue crabs on the local clam population and production should be evaluated.

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